amber

MP MASTER
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# AMBER MODEL 3501

# DISTORTION & NOISE MEASURING SET

Issue 01

May 1982

## OWNER'S MANUAL

## SECTION 1

## GENERAL INFORMATION

OWNER'S MANUAL

OPERATING and SERVICE MANUAL

Issue 01 January 1982

1. GENERAL INFORMATION


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# 1. GENERAL INFORMATION

## 1.1 Instrument Description

The Amber model 3501 Distortion and Noise Measuring Set incorporates in a single compact enclosure an ultra low distortion sine wave generator, a high performance total harmonic distortion measuring system and a wide range, high sensitivity signal level and noise measuring facility.

In addition, a tunable band pass filter is included allowing the system to function as a selective voltmeter or manual spectrum analysis. This filter may also be configured as a low pass filter for band limited noise measurements.

The instrument incorporates a comprehensive set of user modifiable filters for noise measurements to various standards and band limiting in the distortion mode.

As an option, the instrument may be also fitted with an additional oscillator and an Intermodulation Distortion measurement facility.

The instrument contains a high efficiency power supply and may optionally include an internal rechargeable battery and charger. It may be powered from North American standard 115V AC mains or, with an option, may be powered from international voltages from 100V to 240V AC.

The model 3501 provides a high level of performance in a size significantly smaller than conventional instruments yet its performance in virtually every parameter rivals that of the best laboratory instruments. Speed of operation and speed of measurement have been optimized and automatic operation is provided for many functions.

## 1.2 SPECIFICATION

### GENERATOR

FREQUENCY RANGE:

10Hz to 100kHz in four overlapping ranges. Continuously variable FREQUENCY control provides selection of any frequency.

OUTPUT AMPLITUDE:

Unbalanced: +20dBm maximum into a 600ohm load to -60dBm minimum.

With balanced output option: +28dBm minimum into a 600ohm load to -60dBm. Oscillator OFF switch disconnects output, shuts off oscillator and terminates output in 600 ohms. May be used for signal to noise measurements.

AMPLITUDE FLATNESS (referred to 1kHz):

20Hz to 20kHz: ±0.1dB
10Hz to 100kHz: ±0.5dB

OUTPUT IMPEDANCE:

600 ohms ±2%, unbalanced or balanced

OUTPUT CONFIGURATION:

Unbalanced: Floating BNC connector
Balanced : Ring-Tip-Sleeve connector

OUTPUT LEVEL CONTROL:

9 steps of 10dB and variable control of 12dB

SIGNAL DISTORTION:

(Load 600 ohms or greater;
output amplitude +20dBV or lower)
10Hz to 20kHz <0.001% (-100dB)
20kHz to 50kHz < 0.004% (-88dB)
50kHz to 100kHz < 0.01% (-80dB)

## DISTORTION, LEVEL and NOISE METER

FREQUENCY RANGE:

10Hz to 100kHz in four overlapping ranges. Continuously variable FREQUENCY control, simultaneously tunes distortion measuring circuits, frequency selective voltmeter and oscillator.

INPUT AMPLITUDE RANGE:

Distortion : +40dBm to -30dBm.
Wide Band Level : +40dBm to -70dBm.
Narrow Band Level or
Band Limited Level : +40dBm to <-120dBm

INPUT IMPEDANCE:

100k ohms $\pm$5% shunted by <100 pf capacitance.

INPUT RESIDUAL NOISE:

(50kHz low pass filter in;
source impedance <1k ohm): <-110dBV or 3uV.

DETECTOR & METER CHARACTERISTICS:

True RMS response for waveforms with a crest factor <3. Response time automatically selected by frequency being measured. Linear dB meter scale reads level in volts, dBm (600 ohms) or dBV (ref 1V) and distortion in % or dB.

ACCURACY:

Level meter, -60dBV or greater
20Hz to 20kHz ±0.2dB
10Hz to 100kHz ±0.5dB

Distortion measurement:
20Hz to 20kHz ±1dB
10Hz to 50kHz +1, -2dB
50kHz to 100kHz +1.5, -4dB*
*for harmonics <300kHz.

FUNDAMENTAL REJECTION:

10Hz to 20kHz > 100dB
20kHz to 50kHz > 90dB
50kHz to 100kHz > 86dB

DISTORTION RESIDUAL OF INSTRUMENT:

10Hz to 20kHz < 0.001% (-100dB)
20kHz to 50kHz < 0.004% (-88dB)
50kHz to 100kHz < 0.01% (-80dB)

AUTO SET LEVEL:

Input range control must be set to within 10dB of correct setting as indicated by LED HI and LO indicators. No manual "full scale level setting" required within this range. Full scale reference will be automatically set provided both LEDs are extinguished.

AUTOMATIC NULL:

When using the internal 3501 generator, distortion measuring circuits are tuned simultaneously with oscillator. When using an external signal source, two LED HI and LO indicators provide a fast indication for manual tuning. When the 3501 distortion measuring circuits are tuned to within about 10% of correct frequency, LEDs will extinguish and the instrument will rapidly and automatically null to maximum fundamental rejection. Tuning indicator LEDs are independent of nulling circuit. Automatic nulling circuit will achieve maximum performance over a full ±10%

range and track source signal frequency drift within this range.

FREQUENCY SELECTIVE VOLTMETER
(NARROW BAND LEVEL):

Inserts a constant percentage bandwidth band pass filter in level meter circuit. Filter is approximately one half octave and may be tuned over full frequency range. Generator frequency tracks center frequency of bandpass filter.

Above filter may alternatively be configured as a 2 pole low pass filter (12dB per octave) with corner frequency equal to generator frequency.

FILTERS:

Four filter positions provided.
Standard filters supplied:
Position 1 : 400Hz High Pass
60dB per decade roll-off.
Position 2 : 30kHz Low Pass
60dB per decade roll-off.
Position 3 : 80kHz Low Pass
60dB per decade roll-off.
Position 4 : optional "A" weighting, CCIR.

INPUT MONITOR:

Scaled presentation of input signal. For external oscilloscope observation of fundamental. Output level: 100mV ±5% for signals with full scale meter readings in level mode. Output source impedance: 600 ohms ±5%.

DISTORTION MONITOR:

Scaled presentation of input signal with fundamental removed. For external oscilloscope or spectrum analysis use. Output level: 100mV ±5% for signals with full scale meter reading in both distortion and level modes. Output source impedance: 600 ohms ±5%.

POWER:

Instrument requires approximately 14V AC at 3A max. An external AC mains transformer is supplied to provide this voltage. The AC mains input is nominally 120V AC +5, -10%, 60Hz. An optional AC mains transformer can be supplied to operate from international voltage sources of 100, 120, 220 or 240V AC, 48 to 62Hz. Power consumption is approximately 50 VA or lower.

DIMENSIONS:

(excluding feet)
114mm H x 292mm W x 356mm D
(4.5in H x 11.5in W x 14in D)

WEIGHT:

(instrument less battery) 3.6kg (8 lb)
(instrument with battery, IMD option, &
AC adapter/charger) 5.5kg (12 lb)

OPERATING ENVIRONMENT:

Temperature 0°C to +50°C
Humidity <95%, 0°C to +40°C

## 1.3 OPTIONS

### 001 : RECHARGEABLE BATTERY, AC ADAPTER/CHARGER

Provides an internal 12V rechargeable battery and a DC-to-DC inverting power supply to generate the two isolated bi-polar power rails to power the generator and measurement circuits. Power supply also includes a battery charging circuit and voltage level detector to automatically shut off instrument when battery voltage falls to approximately 8V.

### 002 : EXTENDED BATTERY and CHARGER

Similar to option 001 above but provides approximately twice the discharge time (about 3 to 4 hours).

### 003 : 100, 120, 220, 240 VAC MAINS ADAPTER/CHARGER

Replaces 120V AC adapter normally supplied with one suitable for international use.

### 004 : BALANCED INPUT

Provides an active differential input configuration for use in professional/broadcast systems or measurements of non-ground referenced sources. Also useful to break ground loops.

### 005 : BALANCED OUTPUT

Provides a floating/balanced output capable of up to +28dRm drive into a 600 ohm load. Front panel switches select Balanced or Unbalanced, Floating or Grounded and Terminated or Unterminated.

### 006 : INTERMODULATION DISTORTION MEASUREMENT FACILITY

Provides second (Low frequency) oscillator and mixing circuitry to provide twin-tone generator signal and intermodulation distortion measurement filters to be used with 3501 meter ciruits. Can generate SMPTE or DIN standard test signal and measure SMPTE, DIN and CCIF type of IMD distortion. Generator HF component can be varied from 2kHz to 100kHz.

model 354 : WEIGHTING NETWORK/FILTER KIT

Provides five popular plug-in filter networks and five unbuilt headers and covers for custom networks.

Model 358 : High Resolution Frequency Meter

This option adds a digital frequency meter to the 3501 to permit accurate measurement of either internal or external signals. A frequency multiplier provides high resolution (0.1Hz) and fast update (100mS) for convenient low frequency use. Auto ranging, input selection and special modes make the 3501 both convenient and simple to use. Mounts in a one inch overbridge on the 3501 cover. May be retrofitted to existing units.

# AMBER MODEL 3501

# DISTORTION and NOISE

# MEASURING SET

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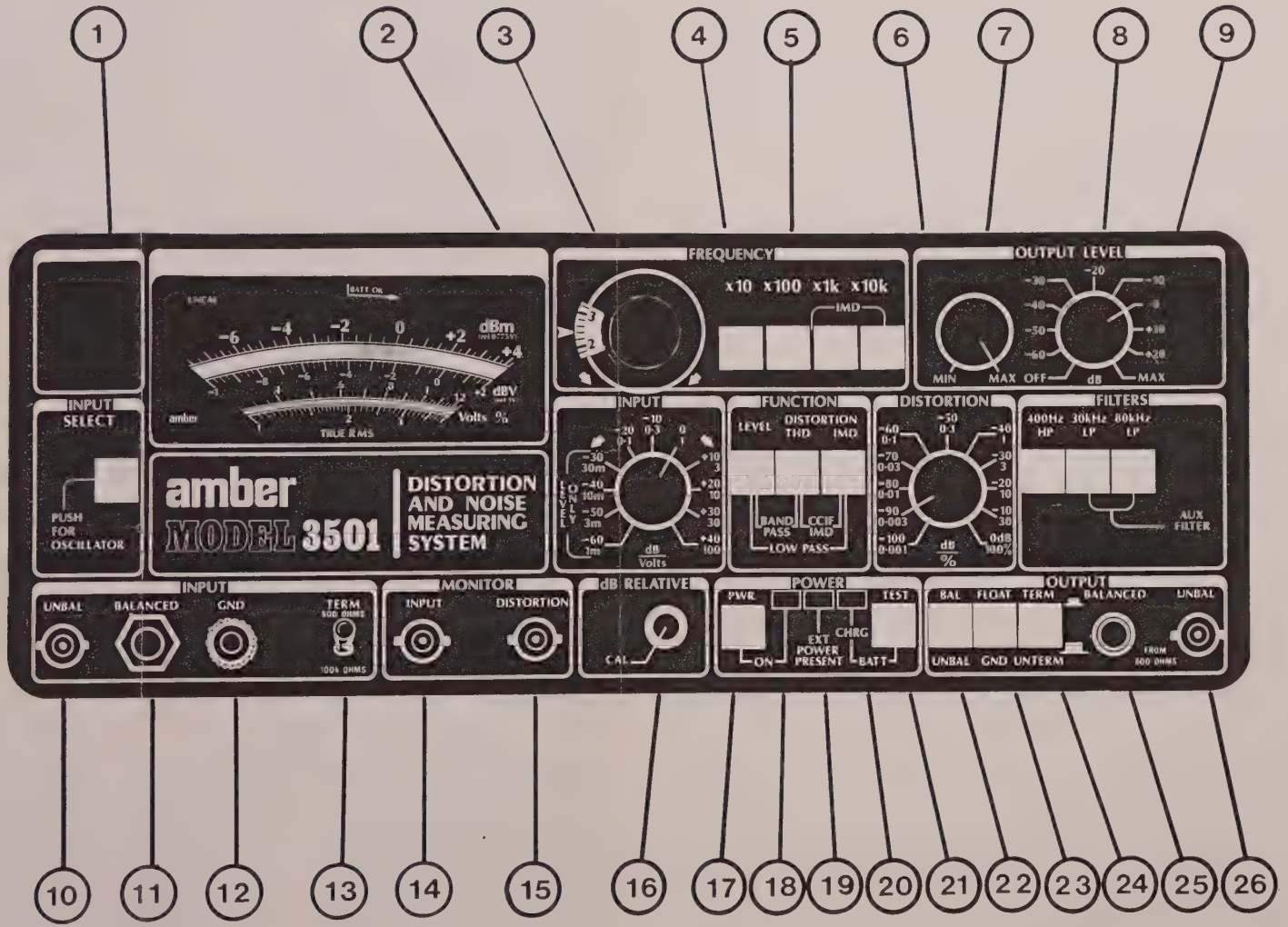
## OWNER'S MANUAL

## SECTION 2

## OPERATING INSTRUCTIONS


1
2
3
4
5
6
7
8
9
INPUT SELECT
PUSH FOR OSCILLATOR
BATT OK
LINEAR
-6 -4 -2 0 +2 +4
dBm
dBV
amber
TRUE RMS
Volts %
amber
MODEL 3501
DISTORTION AND NOISE MEASURING SYSTEM
FREQUENCY
x10 x100 x1k x10k
IMD
OUTPUT LEVEL
MIN MAX OFF dB MAX
INPUT
PREAMP ONLY
dB
Volts
FUNCTION
LEVEL
DISTORTION
THD IMD
BAND PASS
CCIF IMD
LOW PASS
DISTORTION
dB
%
FILTERS
400Hz HP
30kHz LP
80kHz LP
AUX FILTER
INPUT
UNBAL
BALANCED
GND
TERM 600 OHMS
100k OHMS
MONITOR
INPUT
DISTORTION
dB RELATIVE
CAL
POWER
PWR
ON
EXT POWER PRESENT
CHRG
BATT
TEST
OUTPUT
BAL FLOAT TERM
BALANCED
UNBAL
UNBAL GND UNTERM
FROM 600 OHMS
10
11
12
13
14
15
16
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1) INPUT SELECT PUSHBUTTON. Selects input to analyzer. Push in to read the GENERATOR OUTPUT LEVEL delivered to the external load. Release to read the INPUT signal.

2) INPUT control determines input sensitivity. Set for an on-scale meter reading in the LEVEL mode or to extinguish the HI and LO LED warning indicators in other modes.

3) FREQUENCY vernier control. Sets significant digit of oscillator and analyzer frequency.

4) FUNCTION pushbutton group. Basic functions of LEVEL, TOTAL HARMONIC DISTORTION and INTERMODULATION DISTORTION are set by pushing one of the three buttons. Special functions of BAND PASS LEVEL, LOW PASS LEVEL and CCIF INTERMODULATION DISTORTION are selected by pushing two buttons together. (Note IMD functions operational only if option 006 is installed.)

5) FREQUENCY RANGE pushbutton selects multiplier of number set by rotary vernier knob.

6) DISTORTION control determines meter sensitivity. Set for an on-scale meter reading in the DISTORTION mode or the BAND PASS/LOW PASS mode.

7) OUTPUT control provides a nominal 12dB variation of output level.

8) OUTPUT attenuator sets the nominal 10dB step of output range. With correct output termination (load impedance) steps will be exactly 10dB.

9) FILTER pushbutton group. Chooses appropriate selection from four available filters. Three standard filters selected by pushing in one or more of the three buttons. Fourth (AUX FILTER) filter position selected by pushing in second and third button simultaneously (only functional if optional fourth filter installed).

10) UNBALANCED INPUT connector. Use for single ended sources. Shell of BNC connector is normally connected to chassis but floats when PUSH FOR OSCILLATOR is pushed. Input impedance set by (13) is 100k ohms or 600 ohms in parallel with about 100pf.

11) BALANCED INPUT connector. Ring, tip and sleeve telephone-type connector for balanced inputs. Sleeve is chassis when INPUT is selected. Inserting a plug disconnects the UNBAL input. (Balanced mode functional only if option 004 is installed.)

12) GROUND post is normally connected to chassis but floats when PUSH FOR OSCILLATOR is pushed.

13) INPUT TERMINATION switch selects input impedance for both balanced and unbalanced inputs.

14) INPUT MONITOR connector presents a scaled replica of INPUT signal after INPUT control.

15) DISTORTION MONITOR connector presents a scaled replica of signal being measured: the input signal in LEVEL, distortion residual components in DISTORTION and the selective filter output in BAND PASS or LOW PASS.

16) dB RELATIVE control allows meter reading to be offset up to ±12dB to set an arbitrary zero dB reference.

17) POWER ON/OFF pushbutton. Turns instrument on and off using either internal (battery) or external (transformer) power source. Will turn off automatically on low battery.

18) POWER indicator. Red LED indicates unit is ON. When optional battery reaches last 10% of life, LED starts to blink. Blinking rate increases as battery nears end of discharge until instrument automatically shuts off.

19) EXTERNAL POWER PRESENT indicator. Green LED indicates the presence of adequate external power source, typically AC mains via the wall plug transformer. Will extinguish if mains voltage is too low or internal fuse opens.

20) CHARGE indicator. Orange LED indicates high-charge rate of battery charging. When battery is fully charged, indicator will extinguish and charger will switch to a float charge mode. High-charge rate may require instrument to be switched off. (Functional only if option 001 or 002 battery is installed.)

21) BATTERY TEST pushbutton. Switches measurement meter to battery to measure battery charge condition. Should be pushed with instrument turned on. A reading of mid-scale ("BATT OK") or greater indicates satisfactory battery charge. Deflection is approximately proportional to charge life available. (Functional only if option 001 or 002 battery is installed.)

22) BALANCED/UNBALANCED pushbutton. Functional only if option 005 Balanced Output is provided. With button out, generator output is present on UNBAL BNC connector and in a single ended mode on the ring-tip-sleeve jack. With button in, optional balancing system is inserted and a balanced output appears at the R-T-S jack.

23) FLOAT/GROUND pushbutton. In unbalanced mode, button in sets shell of BNC and sleeve-ring of jack to a floating condition with respect to instrument chassis and input ground. With button out, all grounds are common. In balanced mode button in sets R-T-S jack to complete float condition. Sleeve is center tap of output and floats with respect to instrument ground. With button out, sleeve and center tap are connected to instrument common ground.

24) TERMINATE/UNTERMINATE pushbutton. With button out, output is unterminated. With button in, output is terminated in 600 ohms. Note output source impedance is 600 ohms at all times except when OUTPUT ATTENUATOR is set to MAX when output source impedance is 300 ohms unbalanced, 20 ohms balanced.

25) BALANCED output jack. Ring, tip and sleeve telephone type jack provides balanced output in balanced mode (with option 005) or single ended output (tip and sleeve) in unbalanced mode.

26) UNBALANCED output connector. BNC connector provides unbalanced output. Disconnected in BALANCED mode.

## 2. OPERATING INSTRUCTIONS

### 2.0 INTRODUCTION

This section contains detailed operating instructions for use of the model 3501 instrument. It describes the general philosophy of the instrument, description and use of its operating controls, interface to the device under test and any required external equipment.

### 2.1 PREPARATION FOR USE

The model 3501 is powered by an external source of nominal 14V AC. This is supplied by an external mains transformer. In its standard form, for North American use, this is a "wall plug" box designed to be plugged into a standard nominal 115V AC wall receptacle. This transformer has internal protection against failure by means of an automatically resetting thermal breaker in series with the output to protect against shorts. A captive cable terminates in a four-pin DIN style locking connector. This plug should be connected to the mating connector on the rear panel of the 3501.

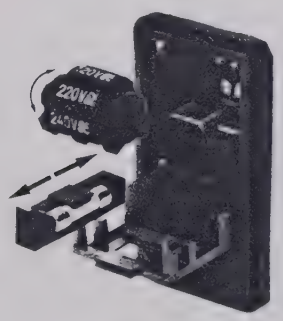



Fig 2.1 **Changing Voltage Taps**
Option 003 International AC Mains Transformer

As an option, an international AC mains transformer may be provided (option 003). This is a box containing the mains to 14V AC transformer, a line fuse, a line voltage selection switch and an IEC standard AC mains receptacle. An AC line cord with a mating IEC plug at one end will also be provided. The other end is prepared for the user's selection of AC mains plug. This cable follows the European standard color code. Before use set the voltage selector to the appropriate settling. This is done by unplugging the mains power cord, pulling down on the access door, rotating the voltage selection drum to the appropriate orientation and closing the access door.

The following table gives the mains voltage range for each nominal selection:

| NOMINAL VOLTAGE | OPERATING RANGE (+5% -10%) | FUSE |
|---|---|---|
| 100 Volts | 90 to 105 Volts | 0.5A |
| 120 Volts | 108 to 126 Volts | 0.5A |
| 220 Volts | 198 to 231 Volts | 0.5A |
| 240 Volts | 216 to 252 Volts | 0.5A |

This international mains transformer supply also contains a captive power cord terminating in a four-pin DIN style locking connector. Plug this connector into the mating receptacle on the rear panel of the 3501.

The instrument may also be equipped with an optional rechargeable battery and charger system.

There are two or more internal fuses in the instrument. One is on the external power input line. A failure of this fuse will prevent the instrument from turning on unless there is an internal, charged battery. It will also inhibit battery charging. The second fuse is on the INPUT line and should only fail if the input signal exceeds the capabilities of the instrument. This would occur if the INPUT control were set to +10dR/3V or lower and the input signal level were +30dBV/40V or higher. If the balanced input option has been provided, two input fuses will be included, one in each input.

## 2.2 SYSTEM DESCRIPTION

The model 3501 Distortion and Noise Measuring set contains two electrically separate but mechanically interlocked sections: a Generator and a Measuring system. As such, it is completely able

to perform measurements without the use of additional equipment although an oscilloscope is very useful.

The system will measure wide band signal level, wide band noise, total harmonic distortion, band limited noise and crosstalk. By extension, it can measure frequency response, noise spectrum, distortion versus frequency and distortion versus level.

The instrument contains a precision ultra low distortion sine wave oscillator followed by a power amplifier and output attenuator. This generator is able to generate the test signals for all the measurements possible in the measuring system. (An exception is CCIF IMD Section 2.13.3.)

Signal and noise levels are measured by a precision variable gain amplifier followed by a true rms detector and analog meter. It is capable of operation over a wide dynamic range of up to 160dB or 100 million-to-one.

The primary function of the instrument is to measure total harmonic distortion. In fact, the more precise description of the resulting measurement is "Total Harmonic Distortion plus Noise". It does this by sending an essentially pure single frequency to a device under test, eliminates this fundamental frequency from the received signal output of the device under test, measures everything that is left and presents this amplitude as a ratio of the total received signal.

For example, assume a test frequency of 1kHz. The 3501 will generate this signal with harmonics greater than 100dB down resulting in an essentially pure signal. For simplicity, assume the device under test is unity gain and we wish to measure THD at 0dBV, i.e. a 1V level. The generator will provide the 1kHz, 0dBV signal to the input of the device under test, the 0dBV signal output will be fed to the input of the 3501. A very deep notch filter (band reject filter) will provide over 100dB of rejection of the 1kHz fundamental. The non-linearities of the device under test will have added components at 2kHz, 3kHz, 4kHz, etc. The RMS meter of the 3501 will measure the amplitude of the sum of these, compare this amplitude to that of the fundamental and display the result as a percentage or dB ratio. If the amplitude of the rms sum of the harmonics were 1 mV in this example, the meter would indicate 0.1% or -60dB.

Since the measuring circuits are measuring the total bandwidth minus only the small fundamental area, they will also measure noise along with the harmonics. In many cases, the noise will be below the harmonics and the measurement will be very close to the true harmonic distortion. In other cases, the noise will be higher and thus the measurement will actually be noise and not

distortion. The use of an oscilloscope to monitor the distortion residual will assist the user in qualifying the measured result. Also see the section on Filters 2.7 following.

## 2.3 RMS DETECTION

Distortion and noise measurements will generally involve complex waveforms. Average-responding meters, which are usually calibrated in rms for a pure sine wave, will give significant errors when attempting to measure these complex waveforms. For this reason, the 3501 employs a precision rms detector in the measurement circuits.

Certain waveforms can yield an error of over 10% when measured with an average responding detector. The rms measuring circuits of the 3501 will provide an accurate measurement of signals with crest factors as high as 10 full scale (see Section 2.5.2 following) This assures accurate indication of distortion and noise signals.

## 2.4 SIGNAL GENERATION

The 3501 contains an ultra low distortion sine wave oscillator, an output power amplifier and an output attenuator. Also included are facilities to measure the output signal level using the 3501 meter.

The generator has a frequency range of 10Hz to 100kHz covered in four overlapping decade ranges. It has an amplitude range of +20dBm to -60dBm unbalanced or up to +28dBm balanced and terminated. It provides continuous tuning and continuous level selection over its full operating range. Although ultra low distortion, it exhibits extremely fast amplitude settling time even at low frequencies. Output source impedance of the generator is 600 ohms at all but one attenuator and level settings including OFF. The exception is the MAX setting of the OUTPUT ATTENUATOR where the output source impedance is approximately 50 ohms unbalanced or 100 ohms balanced. The output low terminal (BNC shell) is isolated from input low and case ground when in the FLOAT mode.

Frequency selection is made using the vernier drive rotary control and four-button switch bank in the FREQUENCY area of the panel. Actual frequency is the indication on the rotary dial multiplied by the number on the selected range. Some overlap is provided at each end of the rotary control to ensure that all frequencies within the instrument range are available. Where the same frequency appears in two ranges (example 100Hz, 1kHz, 10kHz) the preferred selection is the lower range with the rotary control set to 10. (Example 1kHz found by 10 x 100 rather than 1 x 1k)

Output signal level selection is made using the upper right rotary control and the rotary attenuator switch. Actual output level can be measured by pushing the PUSH FOR OSCILLATOR button at the left of the meter. This connects the input metering circuit directly across the output load for precise send level measurements.

An OFF switch position in THE OUTPUT ATTENUATOR provides a convenient means of making signal-to-noise measurements. In the OFF position the output connector is disconnected from the output power amplifier and connected to a 600 ohm resistor. For added safety, the oscillator circuit is disabled to avoid any chance of signal leak through.

### 2.4.1 BALANCED OUTPUT

As an option, the instrument may be provided with a balanced output facility. Two output connectors will be provided – a BNC for unbalanced output and telephone style ring-tip-sleeve jack for balanced output. This will permit convenient interface to conventional patch panels in systems applications.

Three pushbuttons in the OUTPUT section allow choice of output configuration:

a) BAL/UNBAL sets the output to unbalanced single ended mode or the balanced mode. In the balanced mode, an output transformer is used to provide maximum isolation and true balance. Electronic corrective circuitry (patent pending) significantly reduces the distortion contribution of the transformer.

b) FLOAT/GROUND. In the unbalanced mode this allows the oscillator to float with respect to instrument (analyser) ground. In the balanced mode this grounds or floats the transformer secondary center tap.

c) TERM/UNTERM. In the TERM mode this terminates the output with a 600 ohm load resistor.

## 2.5 LEVEL MEASUREMENT (VOLTMETER OPERATION)

The 3501 will measure signal level over the frequency range of 10Hz to approximately 300kHz and from +40dBV (100 volts) to -60dBV (1mV) full scale. See Section 2.8 following for signals below -60dBV.

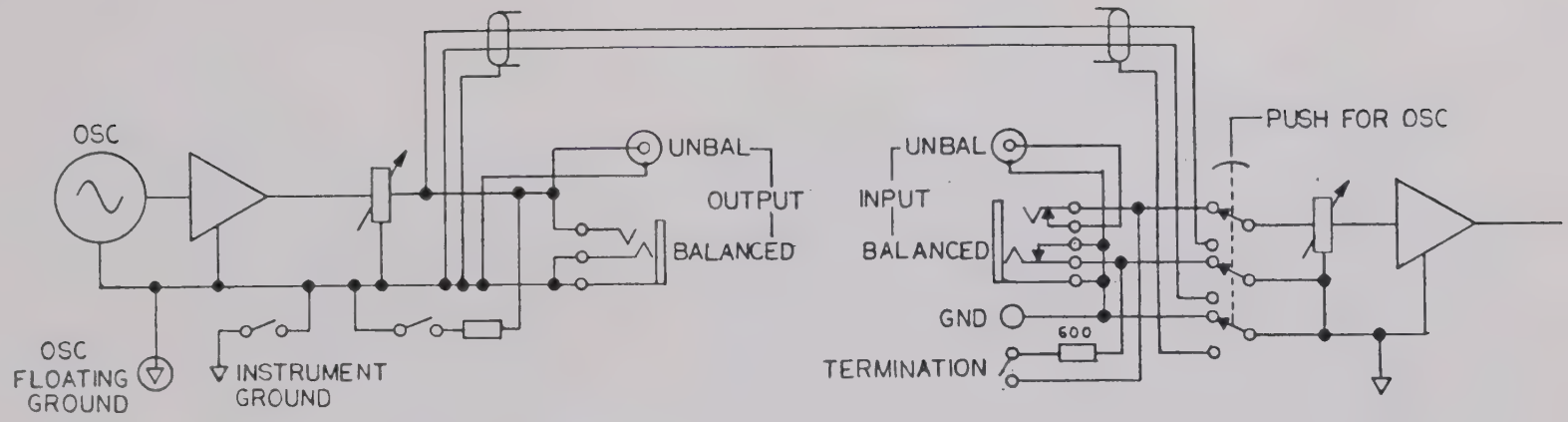
To measure signal level, connect the signal to the appropriate INPUT connector, select LEVEL in the function group and turn the INPUT rotary control until the meter reading is on scale. (Note that the HIGH/LOW warning LEDs only function in the DISTORTION mode.)

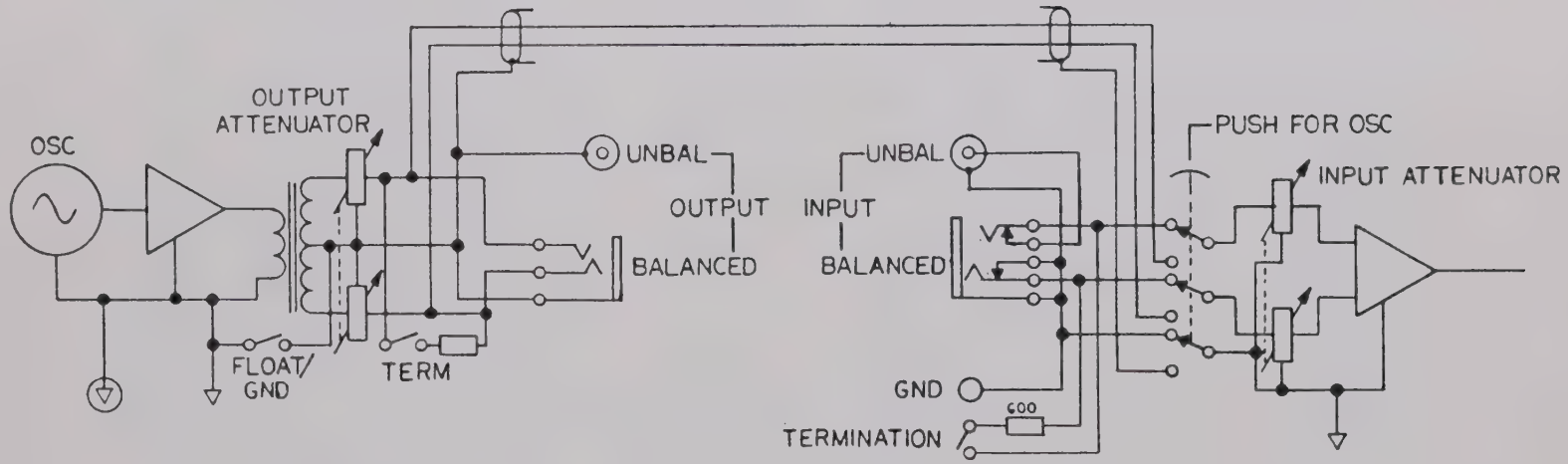
The actual signal level is determined by adding the meter reading in dBV or dBm to the INPUT control selection. Or, to find the reading in volts, use the 1 or 3 scale on the meter as appropriate and the range indicated by the INPUT control. For example, if the INPUT control is pointing to 0.03, use the 3 scale. If the meter pointer shows 2.3, in this example, the actual level is 0.023 Volts or 23mV.

The input impedance is 100k ohms shunted by 100 pf or less. Thus it will provide a sufficiently high impedance load to most circuits to achieve an accurate reading. If the circuit being measured has a high source impedance (over 1k ohm), a correction factor will have to be used due to the loading of the 100k ohm input impedance.

The input preamp contains an active protection circuit. This is designed to protect the sensitive input components from signal overload and cause the fuse to open. As the instrument must measure very low distortion, conventional simple protection circuits are not useable and a sophisticated active circuit must be used. This circuit achieves all the parameters required but can cause difficulties under a particular (and unusual) circumstance. If the 3501 is turned OFF and connected across a source with a finite output impedance, the 3501 will induce distortion in this source. When the 3501 is not powered, the active protection network ceases to function and the input can look like a non-linear load.

For noise measurements the FILTERS may be used in the LEVEL mode. See Section 2.7 following.




INSTRUMENT GROUND SYSTEM

### 2.5.1 BALANCED INPUT

The model 3501 may be equipped with an optional balanced or differential input. In this case a second input preamp and input attenuator are provided. This option permits measurement of non-ground referenced sources or balanced sources as found in professional and broadcast applications. With this option, two input connectors are provided - a BNC for the unbalanced input and a telephone style ring-tip-sleeve jack for the balanced input. The BNC connector is wired via the normalling contacts of the RTS jack. If no plug is inserted in the jack, one of the differential inputs is connected to the BNC receptacle while the second input is grounded. An instrument input ground post is also provided.

An input termination switch is included to allow selection of input impedance. In the down position, the input impedance is 100k ohm to ground in parallel with less than 100 picofarad of capacitance. In the balanced configuration each input is 100k ohms to ground. With the toggle switch in the UP position, a precision 600 ohm termination resistor is added across the input.

### 2.5.2 HIGH CREST FACTOR RMS MEASUREMENTS

The model 3501 has an automatic crest factor compensation facility. This optimizes the noise floor/crest factor capability trade-off that is always present in level measurement instruments.

If the DISTORTION control is set to -80dB/0.01% or lower, the instrument presumes a low crest factor as would be the case with a clean sine wave. In this case the signal amplitude in the preamp and following circuits is maximized to provide the best signal to noise performance. Conversely, if the DISTORTION control is set to -70dB/0.03% or higher, the internal signal level is lowered by 10dB giving greater crest factor handling capability.

All of the level correction required for this manipulation is transparent to the user and is handled automatically by the instrument. The only noticeable difference is the absolute level of the two MONITOR outputs which reflect this 10dB change.

If distortion is being measured, the compensation will be automatic. If only signal level is being measured, set the DISTORTION control to -70dB/0.03% or higher if the signal has a crest factor of greater than about 2. An example would be noise, narrow duty cycle pulse waveforms, signals with high value spikes superimposed, etc.

## 2.6 TOTAL HARMONIC DISTORTION MEASUREMENT

The model 3501 provides a complete THD measurement system by combining a low distortion signal source and an automatic distortion measurement facility. The latter may also be used with an external signal source when required.

When making THD measurements using the internal source, connect the 3501 and device under test as shown in Fig 2.6. It is suggested that an oscilloscope be used as shown to monitor the signals and verify the validity of the measurement. This will show any excessive noise, oscillation, interference or other potential source of error in the measurement.

Set the GENERATOR send level to the level required by the device under test using the procedure shown in Section 2.4 previous. Connect the 3501 OUPUT to the input of the device under test and the output of the device under test to the 3501 INPUT.

If it is necessary to first measure the signal level, proceed as in Section 2.5 previous. If not, push DISTORTION in the FUNCTION group. Turn the INPUT rotary control the appropriate direction if either of the HIGH or LOW red LEDs are on. The proper setting is when both of these are extinguished. Next, turn the DISTORTION rotary control until the meter gives an on-scale reading. The instrument will automatically and rapidly null to a final value as the control is rotated counterclockwise.

Observe the distortion residual components at the front panel MONITOR DISTORTION connector using an external oscilloscope. A typical waveform is one that has a shape close to the second or third harmonic (or a mixture) of the fundamental. A dual trace oscilloscope facilitates this observation. If the waveform exhibits a line synchronous component of 50 or 60Hz there is hum pickup in the test set-up. If a 100 or 120Hz component, it probably indicates an insufficiently filtered power supply in the device under test. See Section 2.7 following. Be cautious of high frequency components indicating RF pickup or device oscillation.

Note that the lowest absolute signal level for distortion measurement is -30dBV/30mV. The lowest effective INPUT control setting is -20dB/100mV. Lower positions of this control (-30 to -60) will not give any increased sensitivity in the distortion mode. If the signal level is too low for distortion measurement (i.e. below -30dBV/30mV) the low red LED will remain on even when the input control is turned fully CCW.

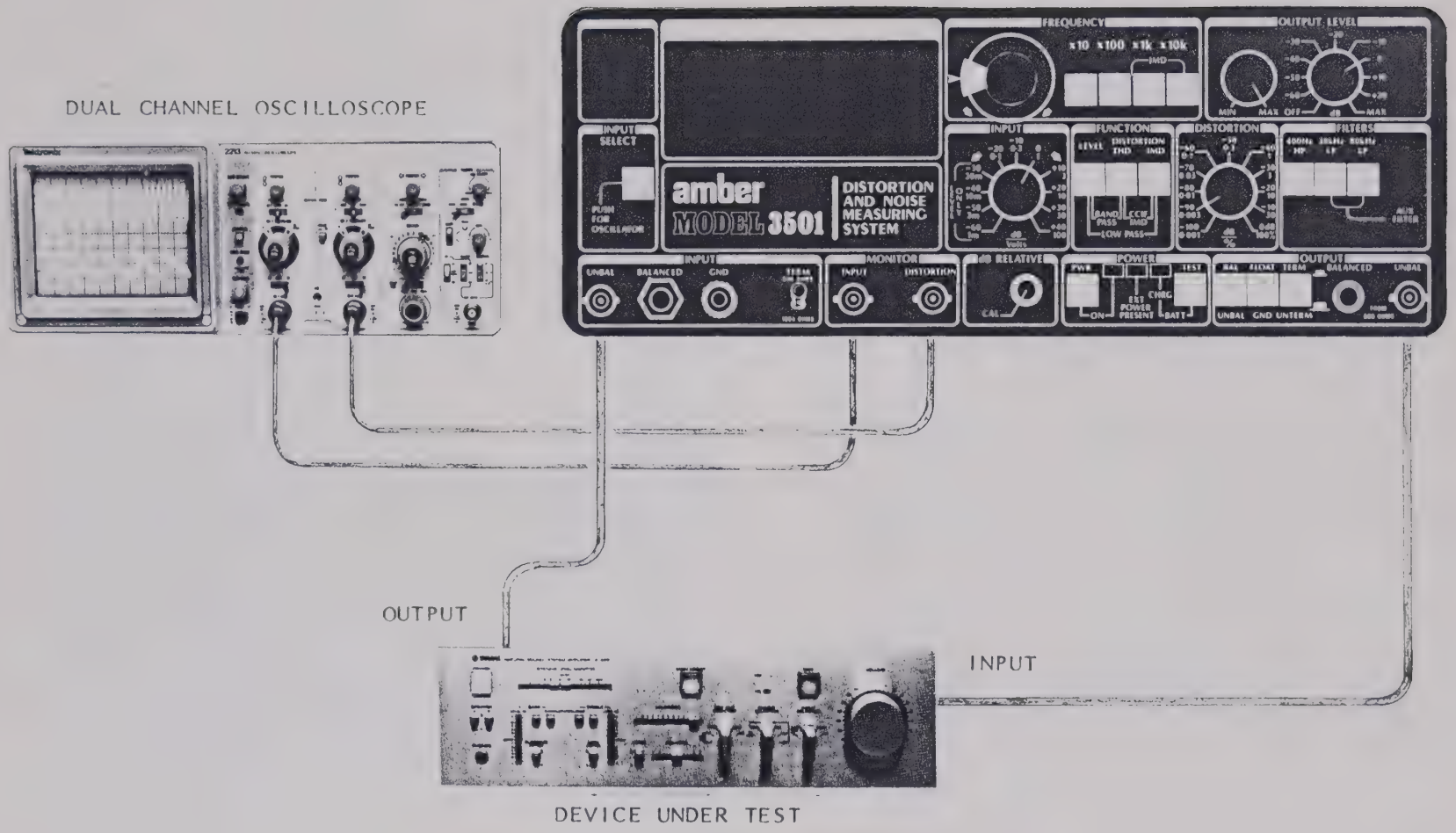



Fig 2.6 Typical setup with 3501,
oscilloscope & device under test

## 2.7 USE OF FILTERS

The 3501 contains four front panel selectable filters which can enhance the accuracy of many measurements. For example, if the device under test is picking up mains hum this will influence the measurement and give an erroneous DISTORTION reading. Although it is necessary to be aware of these offending signals, it is useful to be able to separate the DISTORTION and NOISE readings.

### 400Hz HIGH PASS FILTER

This is an 18dB per octave (60dB per decade) filter useful to eliminate mains hum and other low frequency noise from the measurement. Its 3dB point or corner frequency is 400Hz and it may be used on signals whose fundamental is above 300Hz or so. It will provide approximately 50dB attenuation of 50 or 60Hz interference.

### LOW PASS FILTERS

These are 18dB per octave (60dB per decade) filters useful to eliminate noise, RF interference, high frequency oscillation and, in general, to reduce the measurement bandwidth to gain a few dB improvement on the 3501 noise floor. Their 3dB down points are 30kHz and 80kHz respectively. They may be used to improve distortion measurement with fundamentals below about 6kHz with the 30kHz filter and 20kHz with the 80kHz filter.

### AUXILIARY FILTER

A fourth filter position is provided for specialized noise weighting. It is accessed by pushing both the 30kHz and 80kHz buttons together. A typical application for this filter would be an ANSI "A" weighting filter or CCIR noise weighting curve.

All four filter positions are plug-in networks and may be easily user changeable. Each filter socket is identical and may accept any of the standard or custom filters offered by Amber or constructed by the user.

The filters are always available in any instrument mode. They should not be used in signal level measurement modes such as frequency response measurements. They may be used for noise measurements or to enhance THD distortion measurement. They should not be used in the IMD distortion mode.

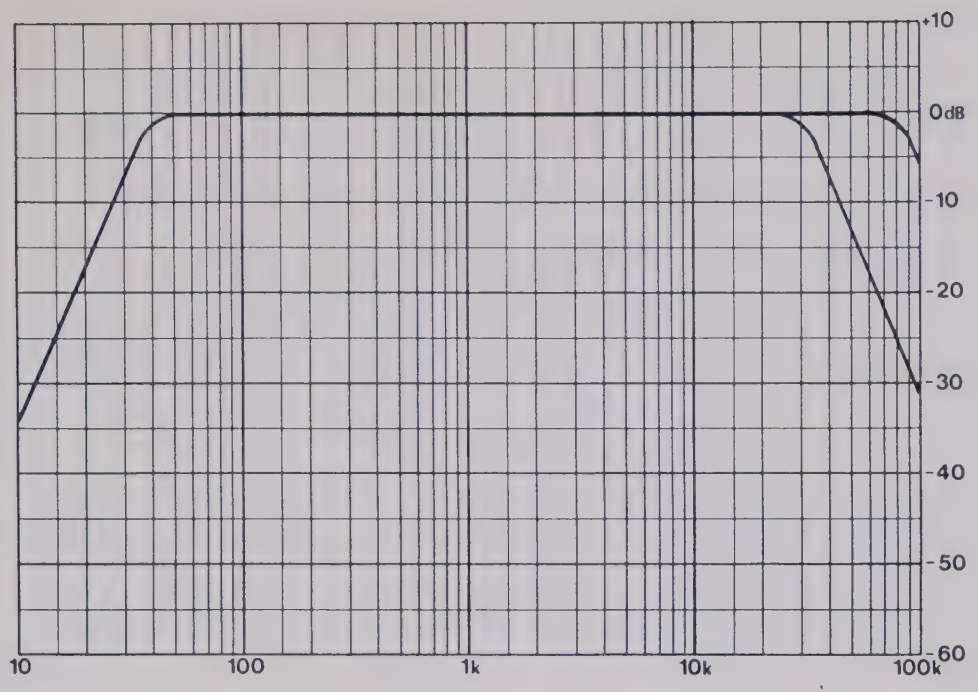



Fig 2.7.1 Three standard filters supplied with 3501

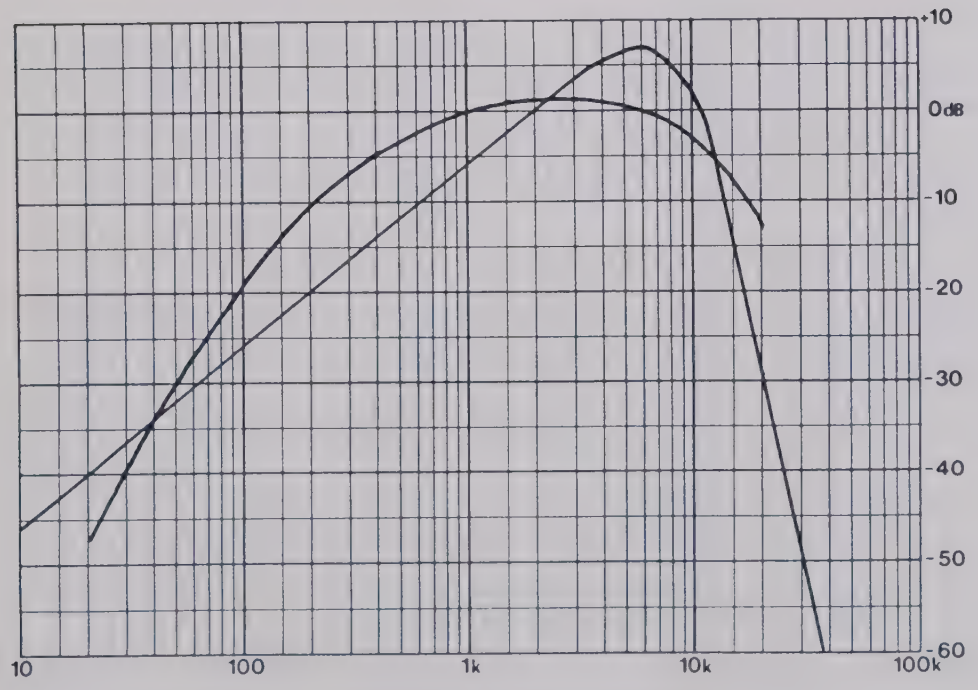



Fig 2.7.2 Example of two optional filters available with 3501

## 2.8 NARROW BAND LEVEL MEASUREMENTS

A unique and very useful feature of the 3501 is the narrow band level measurement capability. This enhances the signal level measurement capability for several measurement situations such as low level noise, crosstalk, signals near the noise floor and acoustic applications.

When the first two FUNCTION push buttons are pushed IN, a band pass filter is inserted in the level measurement path. This configures the instrument as a frequency selective voltmeter enabling it to read signal or noise level in a particular frequency band. The center frequency of this band pass filter is selected by the FREQUENCY controls and tracks the generator frequency.

The shape of the filter is nominally about one-half octave. It is constant percentage bandwidth and is a single pole pair configuration. The shape has skirts which asymptote to 6dB. See Fig 2.8.1.

When using the narrow band mode, both the INPUT and DISTORTION gain controls are effective. The absolute signal level (at the filter frequency center) is the meter reading plus the INPUT control selection plus the DISTORTION control selection with the following notation. In this mode (as in the DISTORTION mode) the INPUT control has no greater sensitivity than -20dB. That is, the -30, -40, -50 and -60 positions give the same effect as -20. Therefore to measure low level signals first turn the INPUT control to -20 and then the DISTORTION control to the position that gives an on-scale meter reading. For example, if the meter reading is -4.5dBV, the INPUT control is at -20 and the DISTORTION control at -70, the actual absolute signal level is:

$$\text{Signal level (dBV)} = 4.5 + (-20) + (-70) = -94.5\text{dBV}$$

The 3501 can also be configured to be a low pass filter. This is achieved by pushing the first and third FUNCTION button. In this mode the corner frequency is set by the FREQUENCY controls. The filter has a 12dB per octave rolloff. See Fig 2.8.2. Level measurement is the same as the BAND PASS mode.

The low pass configuration is particularly useful for noise measurements in a specific bandwidth. For example, to measure the noise in a flat spectrum to 10kHz or 20kHz just tune the FREQUENCY control to that frequency and proceed as above.

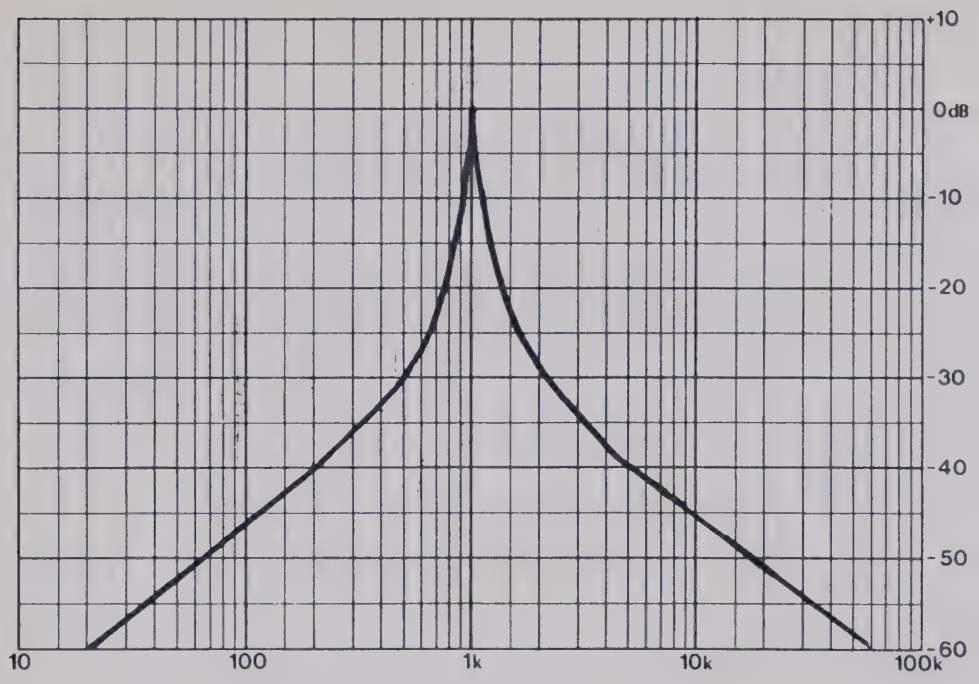



Fig 2.8.1 Response of tunable filter
in BAND PASS mode

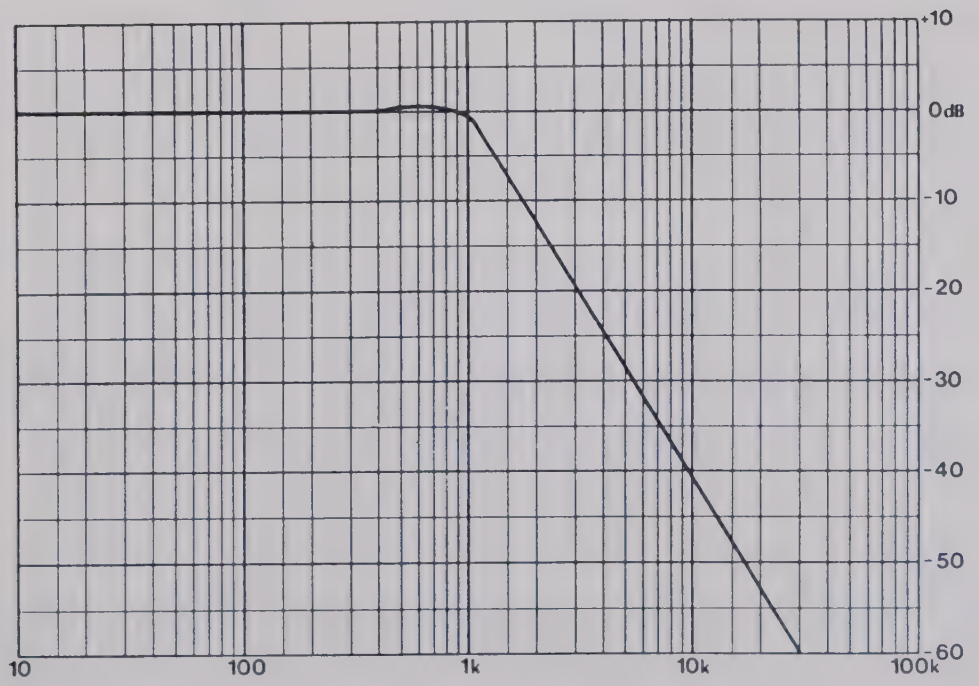



Fig 2.8.2 Response of tunable filter
in LOW PASS mode

## 2.9 dB RELATIVE MEASUREMENTS

This front panel rotary control can offset the meter readings by up to + or −12dB. Using this control the current reading can be adjusted to "0dB" so subsequent readings will be in dB, relative to this first one. This control can be used in any mode although in general it will only be used in the LEVEL mode.

For example, to measure frequency response "relative to 1kHz":

a) Set the generator to 1kHz.
b) Select LEVEL and make an on-scale reading as described in 2.5 previously.
c) Adjust the meter pointer to 0dBV or 0dBm using the dB relative control.
d) Readjust the FREQUENCY control to other frequencies and note the variation in dB relative to 1kHz.

Note that an "UNCAL" red LED will be lit in the meter scale area when the dB relative feature is being used as a reminder to return it to the detented off position after use.

### 2.9.1 SIGNAL TO NOISE MEASUREMENTS

Signal to noise measurements are used to qualify the noise performance of a device under test. They are expressed as a dB figure relating noise floor to normal signal level -- the larger the number, the lower the noise floor and hence the better the performance.

Signal to Noise Measurements (S/N) can be easily made using the 3501. First, it is necessary to establish the signal reference point. This is based on tradition, manufacturers' choice, a particular standard or other source. For amplifiers it is usually the full power level or clipping point. For processing equipment it is usually the operating level or program level (possibly 10 or more dB below clipping). For tape recorders it is the level that produces a particular amount of distortion, perhaps 3% or 1%. Consult the manual for the device under test or the standard to determine the Reference Signal Level.

The second factor is the measurement bandwidth and any possible bandwidth weighting. These factors can have a very significant effect on the measured figure and it is essential to use the specified procedure. For example, tape recorders are usually measured using ANSI/IEC "A" weighting. Amplifiers and signal paths are often measured using a flat "program weighted" or "audio" bandwidth of 20Hz to 20kHz. Virtually all standard weighting characteristics can be produced by a 3501. Some may require the addition of an accessory in the form of a plug-in network. For example, "A" weighting can be provided as a simple

module; "audio" bandwidth by the low pass configuration described in Section 2.8.

Having established the proper reference signal level and weighting we can now proceed to the S/N ratio measurement.

Step 1:

With the weighting (Filters) not selected establish the correct Reference Signal Level at the output of the device under test. This may require a Distortion measurement, Wattage measurement or other condition.

Step 2:

With the 3501 in the LEVEL mode, reading this Reference Signal Level, adjust the dB RELATIVE control to obtain a 0dBV meter reading.

Step 3:

Turn off the GENERATOR of the 3501 using the OUTPUT ATTENUATOR. Select the appropriate WEIGHTING filter, if required.

Step 4:

Select the LOW PASS function by pushing the first and third FUNCTION buttons. Turn the FREQUENCY control to set the upper cutoff frequency - usually 100kHz or 20kHz.

Step 5:

Turn the DISTORTION control to obtain an on-scale meter reading (without changing the previously set dB relative control).

Step 6:

Add the meter reading on the dBV scale to the dB value on the DISTORTION control to obtain the correct signal-to-Noise value.

For example, suppose the Reference Signal Level is established to be +8dBm. The INPUT control is set to +10dB/3V, LEVEL is selected and a meter reading of -2dBm is noted. This reading is changed using the dB relative control to 0dBV, the OUTPUT LEVEL attenuator set to OFF and the required weighting selected. The FREQUENCY is set to perhaps 20kHz and the LOW PASS mode selected. The DISTORTION control is turned until an on-scale meter reading is obtained. If this happens at say -70dB and shows a meter reading of say -4.5dBV, the correct signal-to-noise ratio is -74.5dB.

## 2.10 MONITOR OUTPUTS

These front panel outputs provide a signal for external observation. They will normally be connected to an external oscilloscope but can also be connected to an external low frequency spectrum analyser to improve the distortion measurement resolution.

### 2.10.1 INPUT MONITOR

This output is a scaled representation of the INPUT signal. It is after the input attenuator and presents a signal for an external oscilloscope for Fundamental monitor or trigger purposes. The output signal level is approximately -10dBV or 300mV for full scale readings in the LEVEL mode and DISTORTION control settings of -80dB/0.01% or lower. For DISTORTION control settings of -70dB/0.03% or higher the signal is 10dB lower (i.e. -20dBV or 100mV). Output source impedance is approximately 600 ohms.

### 2.10.2 DISTORTION MONITOR

This output is a scaled representation of whatever the meter is indicating. In the LEVEL mode, it is the signal being measured. In DISTORTION it is the distortion residual products. In the NARROW BAND mode (BAND PASS and LOW PASS) it is the filter output. The signal levels are the same as the INPUT monitor described above.

## 2.11 POWER SUPPLY

The enclosure of the 3501 contains the regulated power supply and optional battery and charger.

This supply operates from a nominal 14V AC and produces the two isolated bipolar supply rails required by the instrument. ($\pm$15V for the measurement circuits and $\pm$20V for the generator circuits). It contains a high efficiency switching type inverter using state of the art techniques such as VMOS transistors and operates outside the measurement bandwidth (approx. 600kHz) to avoid interference.

An external mains transformer is supplied to provide the nominal 14V AC to the power input connector. Alternatively, a DC source could be provided to power the instrument. The voltage of this DC source should be 10 to 16V for instrument operation and 18 to 20V for internal battery charging. This source may be provided at either polarity.

## 2.12 OPTIONAL RECHARGEABLE BATTERY

If this option is supplied, an internal rechargeable battery is provided in addition to the above described power supply.

The supply also includes a battery charging circuit and battery voltage detector circuit. During operation from the battery (or external power source) the 3501 will automatically switch off when the battery (or external source) falls below approximately 9 Volts. This will avoid total discharge of, and consequent damage to, the battery.

A BATTERY TEST push button switch is located on the front panel. This uses the front panel meter to indicate battery voltage. Mid-scale corresponds to approximately 8V and is indicated by a reading of -4dBV or 2 on the Volts/% scale. A fully charged battery will indicate approximately +1dBV or 3.5 on the V/% scale under load (i.e. 3501 operating).

The red POWER ON LED will indicate when the battery life is in the last 10 percent of its range. It will flash at a rate indicating the remaining time starting at a slow rate when about 90% of the battery is consumed and increasing until automatic shut-off.

### 2.12.1 BATTERY CHARGING CONDITIONS

To charge the battery, connect the external mains transformer (or a user supplied source of 14V AC or 18V DC) to the 3501 power input connector. The battery will charge in 6 to 12 hours with this source and the instrument turned off. It will not charge with the instrument turned on (nor will the battery be discharged). During this charge period, the front panel CHRG LED will light. At the completion of charge, the charger will automatically revert to a float mode and the LED will be extinguished. It can remain in this mode indefinitely.

Do not allow a discharged battery to sit for an extended period (more than a few days) prior to recharging.

### 2.12.2 BATTERY DISCHARGE CONDITIONS

With option 001, a fully charged battery should give between one and two hours of continuous use before automatic shut off. If it is not used continuously, the total discharge time can be extended beyond this time. Option 002 gives approximately twice this discharge time.

If the instrument is allowed to run until shut off, then left to sit for several hours, it should be possible to obtain additional time before recharging. However, if possible, avoid this procedure as this deep discharge operation will shorten battery cycle life.

Under proper conditions, a single battery will give 300 to 500 or more charge/discharge cycles. Good battery care includes recharging as soon as possible after discharge and avoiding deep discharge conditions (repeated deep discharge prior to recharge).

### 2.12.3 INTERNATIONAL VOLTAGE OPERATION

For international AC mains operation, the 003 option is provided. This is a transformer box that provides 14 VAC and a cable with the required power connector for the 3501. For mains connection, a power cord with an IEC mains connector on one end is provided to mate with an IEC mains receptacle on the 003. This connector also contains a means of setting the mains voltage to 100V, 120V, 220V or 240V to accommodate various mains conditions. It will operate from 48 to 62Hz without change. A mains fuse is also included.

## 2.13 IMD Distortion Measurement (OPTIONAL)

Option 006 adds IMD measurement and generation capability. Internal changes include the addition of a second oscillator and the IMD measurement circuits. These additional facilities share the input, output and metering functions of the basic instrument.

### 2.13.1 SMPTE/CCIF SELECTOR

The front panel function switch selects one of two IMD modes: SMPTE or CCIF. Select SMPTE by simply pushing the third FUNCTION button labelled IMD. Select CCIF by pushing the second and third buttons simultaneously. The SMPTE mode involves the use of two sine waves, one a low frequency of typically 60Hz and the second a high frequency (7kHz for the normal SMPTE specification) mixed in a 4-to-1 amplitude ratio. The CCIF mode involves the use of two high frequency signals with a small frequency separation, for example 10kHz and 10.5kHz.

### 2.13.2 SMPTE IMD

The 3501 generates the SMPTE type of signal by adding a 60Hz LF sine wave to the existing variable frequency oscillator with the LF amplitude being 12dB higher than the HF. The frequency of the HF signal is set by tuning the front panel FREQUENCY control. Any frequency in the range from 2kHz to 100kHz may be used including, of course, the 7kHz SMPTE standard. The amplitude of this composite signal is internally calibrated to have the same peak amplitude as the equivalent THD sine wave signal. This peak calibration will ensure no clipping at high signal levels but will show a different RMS value on the LEVEL meter.

Measurement of the distortion of the LF + HF signal is identical to the THD measurement described in Section 2.6 of this manual. The INPUT and DISTORTION controls are set as in THD and the INPUT and DISTORTION MONITOR connectors provide oscilloscope outputs. The FILTERS should not be used in the IMD mode. The Low Pass filters are redundant and will show no significant change. The 400Hz High Pass filter would incorrectly eliminate the distortion components which may apppear at 60Hz, 120Hz, etc.

To repeat: use the instrument in the same way as THD but be sure the FREQUENCY is above 2kHz and don't use the filters.

### 2.13.3 CCIF IMD

The 3501 does not generate the CCIF test signal. This requires the used of two external oscillators mixed with resistors for a 1-to-1 amplitude mix. The test signals should have a minimum value of 2kHz and a maximum frequency separation of 1kHz.

The 3501, when switched to CCIF, will measure the difference frequency component and express this amplitude as a percentage of the RMS sum of the two HF signals. It is somewhat equivalent to a highly sensitive voltmeter with a 1kHz low pass filter at the input. As above, do not use the FILTERS in this mode.

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